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JAPAN - NATIONAL REPORT

STRATEGIC DIRECTION SESSION ST1
Road quality service levels and innovations to meet user expectations

Development of Pavement Technology
Aimed at ConservAting and Improving
Roadside Living Environment

SUMMARY

Effective and efficient conservation and improvement of a roadside living environment can be expected through the implementation of integrated measures for motor vehicles, their traffic flows, land uses along roads, road structure, and other relevant factors. This report focuses on the measures which have been adopted by the Japanese Government in the area of pavement technology to conserve and improve a roadside living environment.

The environmental problems related to roads include traffic noises, traffic-induced vibrations, air pollution along roads and heat island phenomenon which is the temperature rise in urban areas caused by an increase in anthropogenic heat and reduction in green areas by road construction, etc. To cope with these problems, several types of pavements are newly developed as described below.

- Porous elastic surface pavement molded from a mixture of urethane resin and rubber chips produced by cutting used tires has roadside traffic noise reduction effects which are about 12dB to 15dB greater than dense graded asphalt pavements in the case of passenger cars.
- Vibration-reducing pavements has effects that vibration levels at roadway edges immediately after pavement construction can possibly be reduced by 2dB to 8dB by comparison with dense graded asphalt pavements.
- Researches are in progress on development of Air Pollution Cleaning Pavement involving the use of clean solar energy by installing titanium oxide on road surfaces with which air pollutants come into contact before their diffusion, near the source of NOx emission.
- Research work has been pursued to develop water retaining pavements which store moisture inside in order to lower temperature of their surface , and lessen their thermal radiation by reducing the heat stored in the pavements through its evaporation.

Procurement methods for pavement works oriented toward environmental improvement are now introduced on trial basis to conserve and improve a roadside living environment.

Pavements have been constructed based on recipe or method based specifications for many years in Japan. In April 2001, the Road Structure Ordinance in Japan was revised to incorporate the results of pavement technology development into the Ordinance, enhance road user benefits, and reduce user costs by promoting technological innovations in pavements, while adopting performance-based specification .

Foreword

With the growth of motor vehicle traffic, progress of urbanization, and enhancement of public awareness of various environmental issues, there have been growing demands for the protection and improvement of a Roadside Living environment. Effective and efficient conservaction and improvement of a roadside living environment can be expected through the implementation of integrated measures related to motor vehicles□ traffic flows□land uses along roads, road structure and other relevant factors. This report focuses on the measures which have been adopted by the Japanese Government in the area of road pavements in an effort to conserve and improve a roadside living environment.

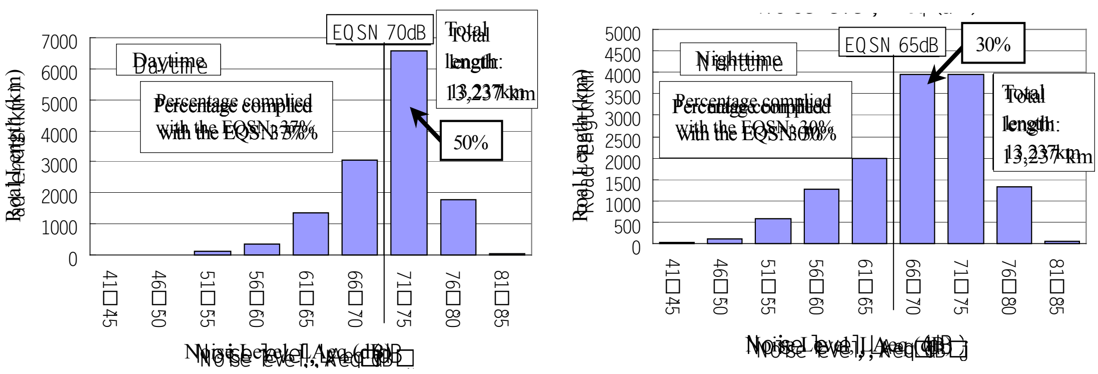
The environmental problems related roads include □traffic noises, □traffic-induced vibrations, □air pollution, and □heat islands phenomenon. Described below in some depth are (1) the state of arts of a roadside living environment in Japan, (2) the development and future problems of Japanese pavement technology aimed at conserving and improving a roadside living environment and (3) the introduction of procurement methods for pavement works oriented toward environmental improvement.

In April 2001, the Road Structure Ordinance was revised in Japan to incorporate the results of pavement technology development into the Ordinance, enhance road user benefits and reduce user costs by fostering technological innovations in pavements. The revised ordinance specifies carrigeway pavements to comply in principle with “standards that permit ensuring the safe and smooth motor vehicle traffic” instead specifying them of being either“cement concrete pavements or asphalt concrete pavements” as stipulated in the old Ordinance. It also stipulates to the effect that carrigeways in urban areas shall, where necessary, have pavements of such structure as “enables smooth permeation of rainwater under road surfaces and lessens road traffic noises.”

1. The State of Arts of a Roadside Living Environment in Japan

□ Present State of Road Traffic Noises

A noise survey conducted on 13,237 km of national roads in urban areas out of a total length of 21,500 km administered by the Ministry of Land, Infrastructure and Transport during the 1996-1998 period revealed that the road length meeting the environmental quality standards for noise levels (Fig. 1) was no more than 37% for the daytime and 30% for the nighttime and that the most frequent noise levels ranged from 71 dB to 75 dB (50%) for the daytime and from 66 dB to 70 dB (30%) for the nighttime. This indicates that a slight reduction in the noise level would contribute largely toward meeting the environmental quality standards for noises.



Daytime   Nighttime

Fig. 1: Road Length by Traffic Noise Levels

□ Present State of Road Traffic-Induced Vibrations

The number of Complaints from residents surveyed about vibrations produced in their neighborhoods totaled about 2,264 in the year 2000, of which 244 (10.8%) were against vibrations induced by road traffic. The occurrence of traffic-induced vibrations tended to be localized because they were often produced by the complexities of local conditions including the ground.

□ Present State of Air Pollution

In Japan, constant monitoring of air pollution has been carried out at a total of 2,119 monitoring stations (1,703 and 416 for air pollution and motor vehicle exhaust gas □respectively□as of 2000) across the country by the Prefectural government and the municipalities designated by the Atmospheric Contamination Prevention Law in compliance with the requirements of this law. The rates of compliance with environmental quality standard for nitrogen dioxide (NO_2) (Fig. 3) at monitoring stations were 99.2% for air pollution and 80.0% for motor vehicle exhaust gas. And there are 494 monitoring stations (322 and 172 stations for air pollution and motor vehicle exhaust gas□respectively) effective in all the areas specified by the Motor Vehicle Nitrogen Dioxide Law (special measures law concerning the reduction of the total amount of nitrogen oxides emitted by motor vehicles in specified areas). Those monitoring stations complying with the environmental quality standards (Fig. 4) numbered 310 (96.3%) for for air pollution and 108 (62.8%) for motor vehicle exhaust gas. (Since 1999 the compliance rates have shown improvements, which□however are considered attributable primarily to climatic conditions and other temporary factors.) The average annual value of NO_2 has leveled off in recent years, indicating that the atmospheric environment of roads in major cities continues to be in a severe condition.

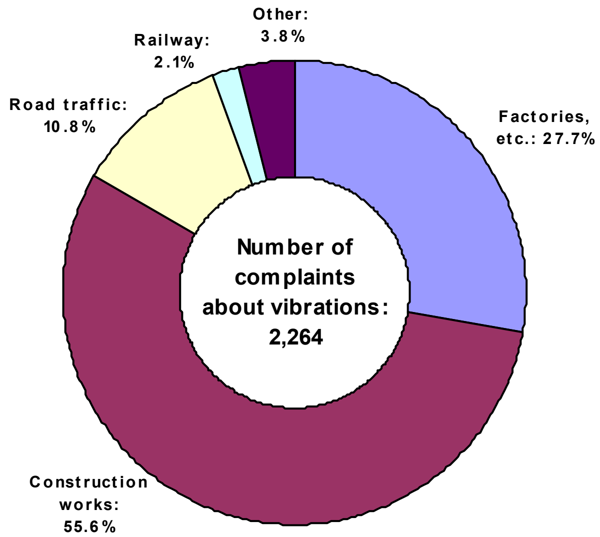


Fig. 2: Percentage distribution of complaints about vibrations by sources (Year 2000)

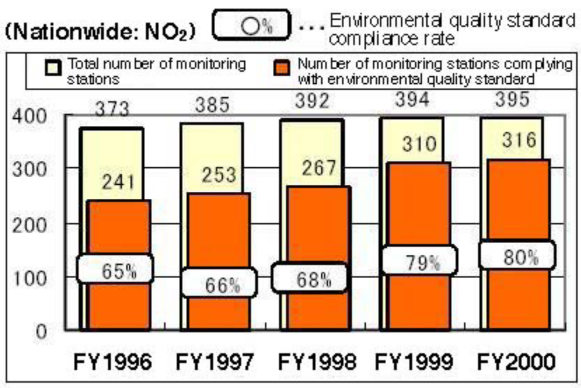


Fig.3: Compliance of environmental quality standard compliance (Nationwide)

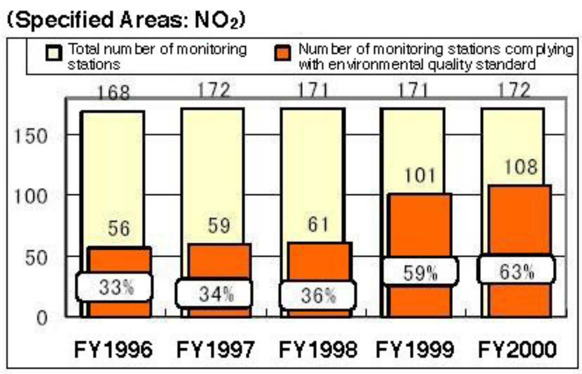


Fig.4: Compliance of environmental quality standard (Specified Areas)

□ Present State of Heat Island phenomenon

The heat island phenomenon □in which the central part of a city or an industrial district has an intensely hotter atmosphere than that of the remaining part (Fig. 5) is a phenomenon experienced not only in Japanese cities but in those of other advanced industrial nations. The number of tropical nights (defined when the lowest temperature is above 25°C) in the summertime of Tokyo averaged 14.6 per year during the 1960s, but it soared to 24.6 in the 1988-1997 period and further rose to 29.6 during the 1991-2000 period. Such an increasing tendency can be seen in other Japanese cities (Table 1). Appropriate measures to cope with the heat island problem are urgently required in pushing forward with our efforts to secure a sound atmospheric living environment and to draw up proper energy-saving measures.

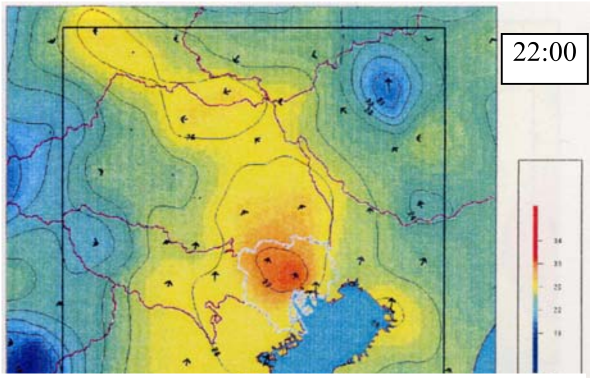


Fig.5: Temperature Distribution in Tokyo Area

Table 1: Changes in Average Annual Number of Tropical Nights

	Sendai	Tokyo	Maebashi	Kofu	Nagoya	Kyoto	Hiroshima	Matsuyama	Fukuoka
1931-1940	0	7.0	0.3	□	0.7	1.7	□	2.3	6.5
1960's	0.2	14.6	0.9	0.4	5.9	9.5	11.4	□	20.7
1988-1997	1.4	24.6	5.8	4.5	17.1	18.7	26.3	□	30.8
1991-2000	1.5	29.6	6.3	□	19.6	23.2	□	19.8	33.7

2. Development and Future Problems of Japanese Pavement Technology Aimed at Conserving and Improving a Roadside Living Environment

(A) Development of Low-Noise Pavement

Pavement□Road traffic-induced noises is classified into two types:
(a) those caused by engines and other machines and (b) those induced by contacts between tires and road surfaces. Low noise pavements incorporating porous asphalt mixtures are used primarily for the purpose of reducing tire□road surface noises. In Japan, low-noise pavements (hereinafter referred to as single-layer low-noise pavement) having a surface layer thickness of 5cm, maximum aggregate particle size of 13 mm, and void ratio of 20% are in wide use. This type of pavement has numbers of voids inside which serve to lessen noises produced by traveling motor vehicles. The reduction effects of road traffic noises are in the range of 2 dB to 4 dB immediately after the construction of single-layer low-noise pavements--- the effects not considered adequate enough by comparison with dense graded asphalt pavements. Moreover, the reduction effects tend to be lost gradually due to clogging or collapsing of the internal voids of the single-layer low-noise pavements. For these reasons, there is a need for new low-noise pavements which yieldgreater noise reduction effects soon after their construction and which are sustainable for a longer period.

Actually, there has been developed a double-layer low-noise pavement in which the upper part of the surface layer is composed of aggregates having a maximum particle size of 5 to 10 mm, smaller values than in the case of single-layer low-noise pavements, to provide smooth road surfaces and thus reduce tire□road surface noises and the lower part of the surface layer consists of coarse aggregates having a maximum particle size of 13 mm to improve resistance against flow. The double-layer low-noise pavements□which are used most extensively in Japan's national highways under the direct control of the Ministry of Land, Infrastructure and Transport ,have a surface layer thickness of 5 cm (2 cm for the upper part and 3 cm for the lower part), maximum aggregate particle sizes of 5 mm or 8 mm (upper) and 13 mm (lower), and void ratios of 23% (upper) and 20% (lower). For passenger cars the noise reduction effects are about 2 dB greater than in the case of single-layer low-noise pavements. Photo1 shows the cross sections of the surface layer of single-layer and double-layer low-noise pavements.

From experiences of trial construction of low-noise pavements incorporating porous asphalt mixtures, the following facts have become known about their noise reduction effects.

- Void ratio: void ratios of 20% or more is necessary.
- Aggregate particle size: The smaller the aggregate particle size becomes (5 mm-10 mm) the less the roughness of pavement surfaces and smaller the tire–road surface noises will be.
- Pavement thickness: Differences in pavement thickness do not influence the noise reduction effects, but it is satisfactory to for the pavement to have a thickness of 3 to 5cm.

(a) Single-layer type (b) Double-layer type

Photo 1: Surface layer structures of single-layer and double-layer low-noise pavements

And the following has become known about the duration of the noise reduction effects.

- In the case of ordinary roads, the noise reduction effects decline rapidly in as early as three to four years after the construction of low-noise pavements. For the present, there does not exist a substantial difference in the durations of noise reduction effects between the single-layer and double-layer low-noise pavements.
- The noise reduction effects last longer for expressways than for ordinary roads. A probable reason is that the progress of clogging of internal voids of low-noise pavements is restrained by suction effects among others on expressways.
- The most important factor contributing toward a decline in the noise reduction effects is considered to be the clogging of voids inside pavements (blocking of voids by dirt, etc.).

The durability of low-noise pavements including resistance to aggregates dispersion is ensured by the use of high-viscosity modified asphalt as a binder. With the widespread use of the high-viscosity modified asphalt, however, its early functional deterioration at locations under severe traffic conditions such as intersections has come into question. The solutions carried into practice for this problem include coating the asphalt surfaces with resin-based material, filling gaps between aggregates with permeable resin mortar, and adding thermosetting resin to the binder to enhance the sustainability and duration of the noise reduction effects.

Double-layer low-noise pavements need to be laid twice at the same site, thus taking longer construction time. For this reason, multi-asphalt paver (hereinafter referred to as MAP), which permits two layers to be laid at a time, has been developed to reduce the construction time. Since a MAP is a larger machine than conventional finishers, manual works are necessary at joints on bridges and viaducts, and at sites where manholes or underground structures are located. In order to avoid lowering operational efficiency, surface evenness and the degree of compaction, it is recommended to carry out overlaying work in advance and to do the finishing after the two layer are laid by a MAP. In addition to that, construction of the double-layer low-noise pavements involves using two types of asphalt mixture at a time, and it is necessary to exercise meticulous care in transporting and supplying the mixtures and in controlling the spreading thickness.

A new machine using water under high pressure for cleaning clogged voids between aggregates has been developed and put to practical use as means to recover the function declined due to the clogged voids of double-layer low-noise pavements. At this stage it is still difficult to achieve complete recovery of the declined function of the pavements, but cleaning efforts made at the initial stage of clogging toward such recovery are likely to result in longer duration of the noise reduction effects of the pavements.

Improved sustainability of the noise reduction effects, development of technology for recovery of declined function of pavements and establishment of an efficient pavement maintenance system are the tasks that should be accomplished at an early date.

Currently, efforts are being made toward a practical application of porous elastic surface pavements molded from a mixture of urethane resin and rubber chips produced by cutting used tires .This new pavement has road traffic noise reduction effects which are about 12 dB to 15dB greater than dense graded asphalt pavements in the case of passenger cars. (See Fig. 7.)

The capability of the porous elastic surface pavements to control traffic noises better than dense graded pavements is attributable partly to the existence of 25 to 30% voids, in terms of volume percentage,inside pavements. These voids can reduce noises produced by the compression and expansion of air when the voids come into contact with road surface. Another factor contributing to the better performance of the porous elastic surface pavements is their elasticity which serves to lessen the impact force applied to traveling vehicle tires by road surfaces. Various tests conducted and measurements taken on porous elastic surface pavements have revealed that they have the following characteristics as low-noise pavements:

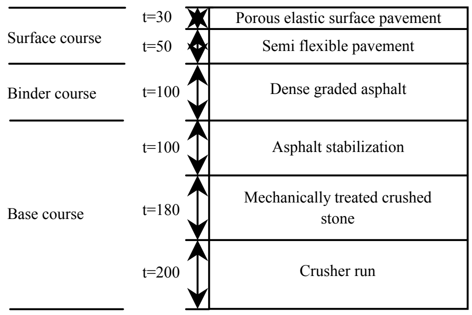


Fig.7: Example of construction of porous elastic surface pavement

- The noise reduction effects of the porous elastic surface pavements (Fig. 8) range from about 12 dB to 15 dB at normal traveling speeds of 40 to 80 km/hr in the case of passenger cars and from about 7 dB to 10 dB in the case of large motor vehicles.
- Speaking of the dependence of the noise reduction effects on traveling vehicle speeds, maximum effects can be obtained at a speed of 40 km/hr, but there can be seen no substantial difference in the noise reduction effects in the traveling speed range of 50 to 80 km/hr. Unlike the case of porous asphalt type pavements, the noise reduction effects do not show a distinct tendency to rise flatly with increasing speed.

Various studies have been conducted on the porous elastic surface pavements to test their strength, durability, fire resistance, and draining capacity and traveling vehicle safety (Fig. 9). These studies have indicated that the porous elastic surface pavements can be expected to exhibit performance characteristics equal to or better than those of dense graded asphalt pavements in terms of greater wear resistance and draining capacity than those of dense graded asphalt pavements. Currently, researches are being pursued on the enhancement of sustainability and duration of the noise reduction effects, improvement of construction works, and cost reduction (Table 2) with a view to practical application of the porous elastic surface pavements. Photos 2 to 4 show the surface characteristics of three different types of asphalt pavement.

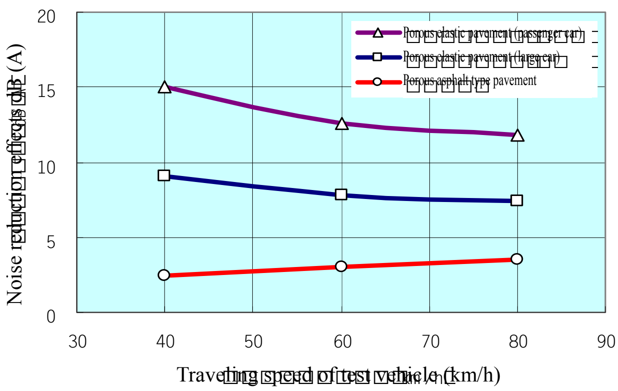


Fig. 8: Noise Reduction Effects of Porous Elastic Surface Pavements (Test conducted in August 2000)

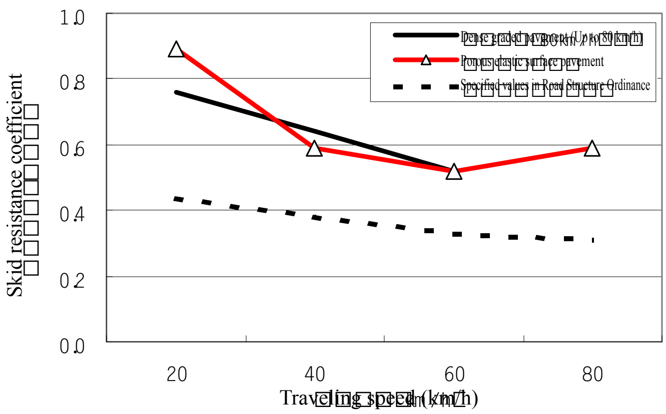


Fig. 9: Skid resistance Coefficient of Porous Elastic SurfacePavement on wet condition

Table 2: Cost Comparison of Different Types of Low-Noise Pavement

Type of Pavement	Dense graded asphalt pavement	Porous elastic surface pavement	Low-noise asphalt pavement
Cost (Dense grade=1)	1	8–10	1.1–1.3

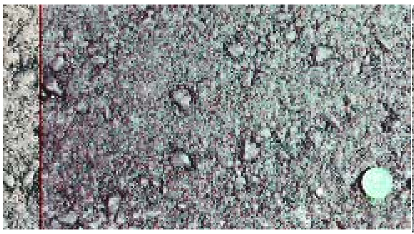


Photo 2: Dense graded asphalt pavement

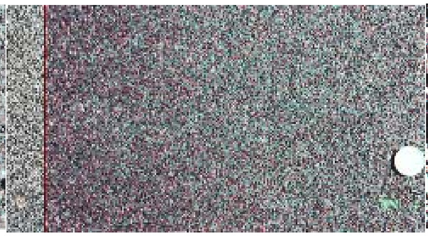


Photo 3: Porous elastic surface pavement

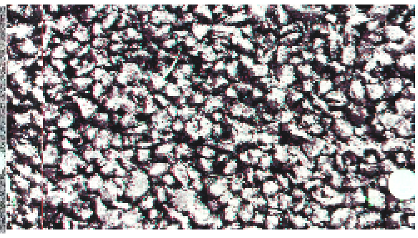


Photo 4: Low-noise asphalt pavement

(B) Development of Pavement to Reduce Vibration

The trends toward larger motor vehicles and growing vehicular traffic in recent years have brought to a roadside living environmental issues relative to traffic-induced vibrations with the result that a need is keenly felt for developing new pavement technology which will bring about greater reduction effects for traffic-induced vibrations. The improvement of subgrade has been considered an effective way of lessening traffic-induced vibrations, but this method is practically difficult to adopt since it usually demands long construction time and large-scale construction works with resulting protracted traffic regulation accompanied by traffic congestion. For this reason, there has existed the need to develop vibration reducing pavements which will allow pavement construction in a relatively short time and serve to lessen traffic-induced vibrations by incorporating surface and subbase course materials. For achieving vibration reductions, it is essential to combine the long-term maintenance of evenness of road surfaces and the use of pavement materials that produce substantial vibration reduction effects. Thus three different types of vibration reducing pavement (Figs.10 to 12 and Table 3) have been developed. They are designed to lesson traffic-induced vibrations by incorporationg one ore more of the following methods:

a) Reducing the propagation of vibrations generated by contact of aggregates by means of voids;
b) Using vibration-proof materials or vibration insulating materials;
c) Using vibration-proof rubber; and
d) Increasing pavement rigidity to high frequency

Further researches are still being made into the three of pavement.

The researches indicate that vibration levels at roadway edges immediately after pavement construction can possibly be reduced by 2 dB to 8 dB whencompared with dense graded asphalt pavements. Enhancing the duration of the vibration reducing effects of the newly developed pavements and the cost reductions (Table 4) are the problems demanding early solution.

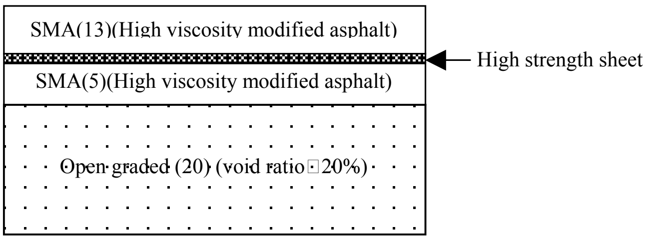


Fig. 10: Pavement ,A

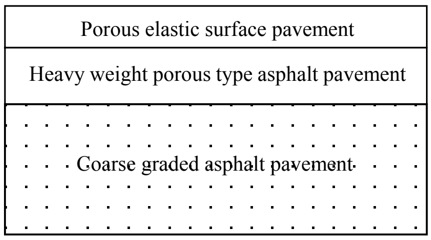


Fig. 11: Pavement, B

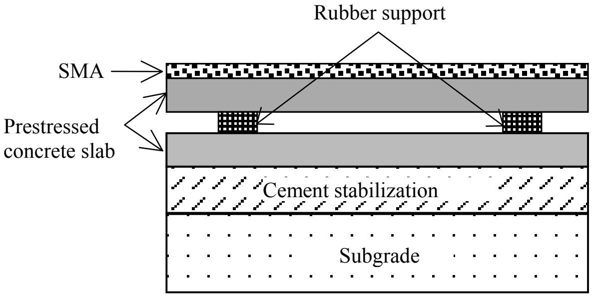


Fig. 12: Pavement, C

Table 3: Physical Properties of Vibration-proof Rubber

Elastic modulus (N/mm^2)	Poisson's ratio	Spring constant (kN/m)
□□	□□	□□

Table 4: Comparison of Different Types of Vibration Reducing Pavements

Type of Pavement	Pavement,A	Pavement ,B	Pavement,C
Cost	Low	Intermediate	High
Construction Works	Easy	Rather difficult	Difficult
Vibration reduction effects	About 3 dB	About 2 dB	About 8 dB

Note: Vibration reduction effects at roadway edges immediately after pavement construction as compared with dense graded asphalt pavement

(C) Development of Pavement to Clean Air

Recent researches indicate that titanium oxide which performs as photocatalysts ,oxidizes air pollutants such as NOx with the aid of solar energy and removes them. The removal capacity is sustained through natural rainfall and periodical cleaning, and is looked upon as a new disposal technology for automobile exhaust gas. Attempts at using materials including photocatalysts for air cleaning and prevention of air pollution have been made by incorporating them in roadside walls, guard rails, noise barriers. Currently, researches are in progress on (1) a efficient air cleaning method involving the use of clean solar energy by installing titanium oxide on road surfaces with which air pollutants come into contact before their diffusion, near the source of NOx emission and on (2) a new pavement structure incorporating carbonized aggregates coated with titanium oxide.

In the case of a efficient air cleaning method of (1) above, field tests indicated that the daily amount of NOx removed was 20 to 30 mg/m^2, amounts considered equivalent to that emitted from daily traffic of 1,000 to 1,500 small motor vehicles. Enhancement of pavement durability and cleaning capacity per unit area, duration of cleaning performance, and pavement cost reduction (currently 3 to 4 times higher than the cost of dense graded asphalt pavement) are the problems facing the air pollutin cleaning pavements that need to be solved early. However, these pavements have advantages: lower installation cost; no need for electric power supply after installation; and no need for special space for installation. In the case of the new pavement structure incorporating carbonized aggregates coated with titanium oxide, laboratory tests indicated that the cleaning capacity of the new pavement structure could be expected to be nearly 10 times larger than the air pollution cleaning pavements. Tests on them demonstrated that the carbonized aggregates had lower density and greater water absorption than ordinary aggregates (Table 5). the carbonized aggregates meet the target values of crushed stones used in pavements in terms of abrasion loss, stability, and stripping resistance (Table 6), and they may be fit for use as pavement aggregates. Researches are made into the method of constructing pavement where the surfaces of carbonized aggregates come into contact with air to maximize air cleaning effects, and enhancement of duration of air cleaning effects and durability for such pavement.

Table 5: Measurements of Density and Water Absorption of Carbonized Aggregates

Type of aggregate	Applicable grading	Surface dry density (g/cm^3)	Absolute dry density (g/cm^3)	Water absorption (%)
Coarse aggregate	Crushed stone (13-5)	1.386	0.851	62.8
	Crushed stone (5-2.5)	1.396	0.876	59.4
Fine aggregate	Coarse grained sand	1.656	1.450	12.3
	Fine grained sand	1.638	1.421	13.1

Table 6: Physical Properties of Carbonized Aggregates

Item		Measured value	Target value
Abrasion loss (%)		20.0	Under 30
Aggregate loss (%)	13–9.5 mm	6.7	Under 12
	9–4.75 mm	0.4	Under 12
	4.75–2.36 mm	2.4	Under 12
Stripping area percentage (%)		5	Under 12

(D) Development of Pavement toControl Surface Temperature (Water Retaining Pavement,etc)

One of the causes of the heat island phenomenon ,which has come into question in urban areas in recent years is the obstruction by pavements of the evaporation process of moisture from the ground or their attribute to store heat. Asphalt pavements have a high thermal conductivity and are prone to store heat. They prevent evaporating moisture and when they receive heat as of insolation, they store it and their temperature rise. The heat thus stored in the asphalt pavements warms up the air by thermal radiation or is conducted to human beings. In the summertime when there is a great deal of insolation, it tends to cause the heat island phenomenon. In Japan, research work has been made to develop water retaining pavements which store moisture inside, lower their temperature, and lessen their thermal radiation by reducing the heat stored in the pavements through its evaporation. A water retaining pavement consisting of porous asphalt pavement, in which voids are filled with a material capable of absorbing and storing water ,has been developed (Fig. 13). Field tests have demonstrated that when retaining water content, the existing water retaining pavement can reduce its own maximum temperature by 10 to 15°C by comparison with dense graded asphalt pavements. Simulations made under certain assumptions indicated that the pavement , when introduced in all the roads of Tokyo Metropolis, would be capable of lowering the temperature in the central part of Tokyo Metropolis by some 0.8°C (Fig. 14). For the present, the duration of the road surface temperature controlling effects as computed in the simulation study is no more than two days, although the duration depends primarily on the water content in the pavement. It is necessary, therefore, to develop pavements having longer duration of the road surface temperature controlling effects and to study other effective methods ,including water sprinkling.Recently,new type of pavement ,which has road surface temmparature controlling effects,is developed. It can reduce its own maximum temperature by 30°C,compared with dense graded asphalt pavements when its surface temperature rise to 60°C in summer season without water sprinkling due to surface of pavement coated with specific paint which can reflect infrated rays.

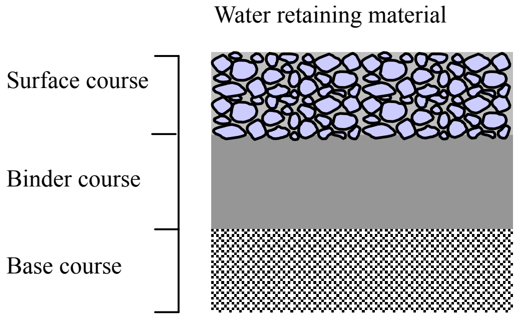


Fig. 13: Cross Section of Water Retaining Pavement

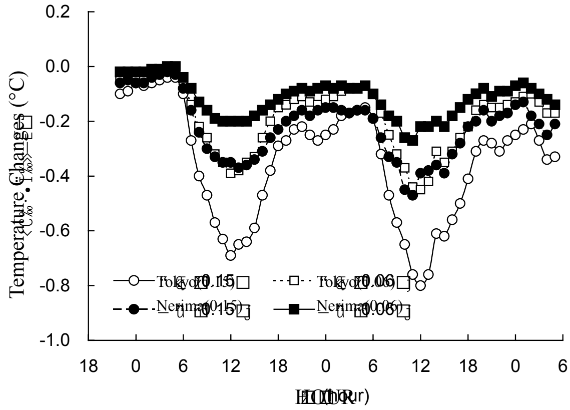


Fig. 14: Temperature Changes with Time Day by Use of Water Retaining Pavements

3. Adoption of New Procurement Method for Pavement Works Oriented toward Environmental Improvement

Since 1998 a new pavement work procurement method has come into force,whereby road surface noise level defined (noise produced between special tire and road surfaces, and measured toclose to the tire) and its measurement required after the completion of pavements as indicator of the pavement performance (performance based procurement method) (Table 7). In the year 2000, introduced in pavement construction on trial basis was the Integrated Environment and Contract Awarding System (Fig. 15), in which pavement contracts are awarded to contractors on the basis of integrated evaluation of price and other factors (environmental improvement effects). Under this system, a pavement contract is awarded to a contractor who, having offered in his or her tender a road surface noise level (after completion of construction) below 89 dB(average value of post-completion road surface noise levels for conventional low noise asphalt pavements) and a tender price below the employer’s estimated price (Note 1), has scored the highest assessed value ,which is to be above the standard assessed value (the value obtained by dividing the score (100 points) for the situation pre-conditional to the employer’s estimated price by this price).

Table 7: Examples of Application of Performance Based Procurement Method

Objet	Item	On completion	After one year
Surface Course	Course	Dynamic stability 4,000/mm and over	□
	Draining capacity	On-site permeability test 1,000ml/15s and over	□
	Evenness	σ=2.4mm or less for each traffic lane	□
	Noise level	Measurements Taken by measuring vehicle (specified tire noise); average value for all lanes should be 89 dB (A) (Leq) or less.	Average value for all lanes obtained in the manner described in left column should be 90 dB (A) (Leq) or less.

Assessed value = (Basic point+ Additional point) ÷ tender price

Company A: Meets the standard assessed value, but its assessed value is lower than that of Company B.

Company B: Has the highest assessed value and is awarded thecontract.

Company C: Has scored the highest points, but is disqualified because of its tender price in excess of the employer's estimated price.

Company D: Is also disqualified because its assessed value is lower than the standard assessed value, although the company has submitted a tender price within the limit of the employer's estimated price.

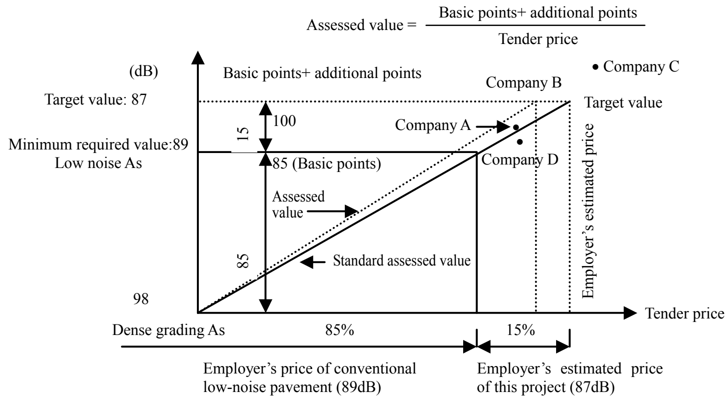


Fig. 15: Basic Concept of Integrated Evaluation and Contract Awarding System for Asphalt Pavement Projects (Example of Practical Application by Kanto Regional Development Bureau, Ministry of Land, Infrastructure and Transport)

Basic point: 85 points
To be given when the lowest required noise level of 89 dB is met.

Additional point: 15 points for each 2 dB reduction achieved.
When a better noise level is proposed, additional points are given according to the noise level reductions proposed.
To be more specific, additional points are given according to road surface noise level reductions proposed with a full score of 100 points for attaining the target value of 87 dB. Additional points exceeding 100 points may be given.

Reference: The proportion of basic points to additional points is established on the basis of the ratio of the construction cost of low noise asphalt pavements complying with standard specifications (average road surface noise level of 89 dB) to the construction cost of the same pavements attaining the target noise level of 87 dB.

In 2001, the pavement technical standards in Japan were revised to provide for pavement performance requirements with the aim of enhancing road user services and achieving user cost reductions through multilateral evaluation of pavement functions and promotion of technical innovations in road pavements.

The established pavement performance indices are (a) number or wheels causing fatigue failure, (b) number of wheels causing plastic deformation, (c) evenness, and (d) amount of water infiltration (where pavements are of such structure as is capable of smooth infiltration of rainwater under road surfaces). The revised standards have enable a freer adoption of pavement structures that satisfy specified performance values according to road classes and planned traffic volumes for pavements.

Note 1) Estimated Price of works attaining the target road surface noise level of 87 dB, calculated on the basis of pavement structure and standard construction method, among others.

Concluding Remarks

In the past, road user services provided by pavements have been evaluated in terms of their evenness, cracking rate, rutting, and other relevant factors from the standpoint of user comfort, safety and cost. For future pavement planning and road improvement, however, it is important to evaluate the road user services from a comprehensive standpoint considering such negative factors as traffic-induced noises and vibrations ,etc as well.